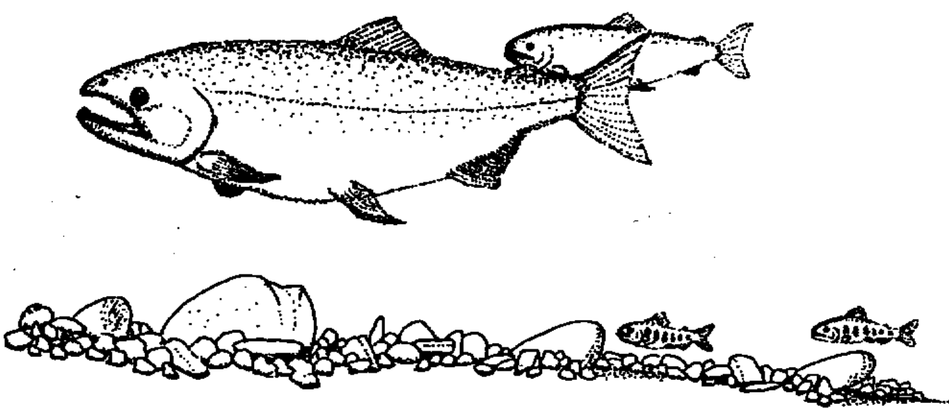
U.S. FISH AND WILDLIFE SERVICE

ELWHA RIVER CHUM SALMON

(Oncorhynchus keta):

SPAWNER SURVEY AND ESCAPEMENT ESTIMATE, 1994-1995



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ELWHA RIVER CHUM SALMON (*Oncorhynchus keta*): SPAWNER SURVEY AND ESCAPEMENT ESTIMATE, 1994-1995

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ABSTRACT

Chum salmon (*Oncorhynchus keta*) spawning escapement to the lower Elwha River in 1994-1995 was estimated by the Petersen mark-recapture technique and three other methodologies. For the Petersen estimate, a total of 17 adult fish were captured in the river with gillnet or at the hatchery rack, then jaw-tagged and released. Fifty-three carcasses on the spawning grounds were examined for tags, and three tags were recovered. From these data a population of 300 spawners was estimated, with a standard deviation of 265. This was a minimum estimate because high streamflow made the spawning grounds inaccessible for survey for two weeks in late December. Supplemental escapement estimates based on redd counts and redd area suggested the 1994-1995 chum run was 238 and 400 fish, respectively, and thus were of the same order of magnitude as the Petersen estimate. Run size was estimated at 203 spawners based on area-under-the-curve method, assuming that 50% of spawners were observed during surveys and spawner stream life was ten days. An estimated 17 Elwha chum salmon (not included in the above run size estimates) were also taken in incidental tribal catch and sport catch in 1994-1995. All estimates suggest the run was almost certainly larger than in 1993-1994.

Live fish counts in the river indicate that chum began entering around 31 October, with peak observed movement into the river sometime in late November and again around 12 December. The second peak may have actually occurred later but would have been unobservable due to high flow. Counts of carcasses and redds indicate that spawning began on 2 November and ended by 3 January, with peak activity on 5 December and again after 16 December, although the second spawning peak was probably unobservable due to high flow. These timing patterns support the hypothesis of a composite run, consisting of an early-spawning native stock followed by a late-spawning introduced stock. However, time gaps in the data prevent clear verification. In contrast to the previous year, the late run segment was much more abundant than the early segment.

The 1994-1995 run spawned predominantly in the left bank side channel and its tributary between river kilometers 1.4 and 3.2. This contrasted with the 1993-1994 distribution, when the mainstem Elwha below that side channel, as well as the right bank side channels between river kilometers 1.2 and 1.8, also supported a large part of the spawning. A large majority of the run returned as four-year-olds, regardless of sex. Males outnumbered females, both in the experimental gillnet catch and on the spawning grounds, by about 1.4 to 1.

Tissue samples from the experimental gillnet catch and from carcasses on the spawning grounds were collected to determine the genetic make-up of the chum salmon run. Those results will be reported separately by the Washington Department of Fish and Wildlife and the Lower Elwha Tribe.

ACKNOWLEDGEMENTS

The Lower Elwha Tribe contributed over half the technician time required for this project. Tribal technicians Joe Turrey and Steve Lauderbach, among others, completed over half the tagging and tag recovery effort under the direction of tribal biologist Doug Morrill. The balance of the field work was also done primarily by FWS technicians Pat Petuchov and Roger Wiswell; Kevin Aitkin and Carrie Cook-Tabor also assisted from this office as needed. Steve Hager analyzed the scales for age determination. Bob Wunderlich reviewed the manuscript prior to interagency review. Dam operators from Daishowa America, Inc. kindly provided stream flow data. The area-under-the-curve escapement estimate was provided by Jim Uehara of the Washington State Department of Fish and Wildlife.

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GLOSSARY

cfs -- Cubic feet per second

Escapement -- The number of fish escaping a fishery to migrate upstream; synonymous with "spawning escapement" "run", and "population" in this study

FWS -- U.S. Fish and Wildlife Service

GSI -- Genetic Stock Identification

LET --Lower Elwha Tribe

Marking -- Application of adipose clip and jaw tag; synonymous with "tagging" in this study

Population -- The number of fish estimated in this study by tagging or redd counts; synonymous with "escapement", "run", "population", and "spawning escapement" in this study

RKM -- River kilometer

RM -- River mile

Run size -- Number of fish entering a river; synonymous with "escapement", "spawning escapement", "run", and "population" in this study

Spawning escapement -- The number of fish escaping the in-river fisheries to spawn; synonymous with "spawning escapement" "run", and "population" in this study

Tagging -- The combination of adipose clip and jaw tag; synonymous with with "marking" in this study

USDI -- U.S. Department of the Interior

WDF -- Washington Department of Fisheries, now Washington Department of Fish and Wildlife

WDFW -- Washington Department of Fish and Wildlife

WWFRO -- Western Washington Fishery Resource Office of the U.S. Fish and Wildlife Service

INTRODUCTION

In October 1992, the "Elwha River Ecosystem and Fisheries Restoration Act" (Public Law 102-495) established in Section 3(d) the goal of full restoration of the Elwha River's ecosystem and native anadromous fisheries. This was to be accomplished by the removal of the Elwha River dams (USDI et al. 1994). Ten anadromous fish stocks, including chum salmon (*Oncorhynchus keta*), were historically present in the Elwha River before construction of the dams in 1914.

The current fish restoration plan (USDI et al. 1994) assumes the dams will be removed and provides prioritized options for the full restoration of all Elwha River anadromous fish stocks. The primary option proposed for restoring Elwha chum salmon is broodstock development for juvenile outplanting, focusing on any identifiable native component as a first priority in brood collection. If the dams are removed, federal, state, and tribal fishery agencies plan to accelerate restoration by releasing hatchery-reared chum fry into the river upstream of the existing dam sites for 8 to 10 yr after safe fish passage is assured.

The genetic identity of Elwha chum is known only from limited tissue samples from 62 spawned-out carcasses collected in 1993-1994 (Wunderlich et al. 1994). Although the sample fell short of the goal of 100 fish, preliminary analysis suggested a remnant, early-returning portion of the run was native based on genetic similarity to other Strait of Juan de Fuca stocks, while a later-returning portion of the run was similar genetically to Hood Canal (Walcott Slough) stock (Steve Phelps, WDFW, pers. comm.).

Partial spawner surveys over the past 40 years suggest a decline in naturally spawning chum followed by a resurgence in 1992, although many gaps in areas and years exist (Wunderlich et al. 1994). The total live and dead count ranged from a high of 414 in 1952 to a low of 1 in 1972. Fish counts were resumed in 1989 and have ranged from a low of 15 in that year to a high of 196 in 1992. Lack of data between 1973 and 1988, coupled with high variability in fish counts in more recent years, prompted WDF et al. (1993) to designate the health of Elwha chum as "unknown". In the 1993-1994 return year, the first season-long spawner survey was conducted (Wunderlich et al. 1994), yielding a peak fish count of 43 and an escapement of 153 adults, estimated by the area-under-the-curve method. The fish counts and escapement estimate failed to account for carcasses and redds that might be hidden beneath the often-turbid waters of the mainstem Elwha River. A population estimate that does not depend on total counts of visible fish or redds would help assess the health of the population.

A better understanding of the abundance, spawning distribution, run timing, and stock identity of Elwha chum will help assess options for stabilizing the run under current conditions, protecting the population in the event of sediment resulting from dam removal, and eventually reestablishing chum in the upper Elwha.

Study Area and Fish Stocks

The Elwha River originates in the Olympic Range of western Washington state and flows northward into the Strait of Juan de Fuca (Figure 1). Dams at RKM 8 (RM 5) and RKM 21 (RM 13) have blocked all upstream fish migration on the river. Since the dams provide little flood control, instream flow downstream varies according to winter storms (Figure 2), and visibility varies inversely with flow.

The run is composed of early-November through early-January spawners, which use primarily the lower 2.4 km (1.5 mi) of the river (Wunderlich et al. 1994). The Elwha Tribal Hatchery had a chum program from 1979 through 1985 based primarily on late-running Hood Canal stock from Walcott Slough, plus a few native Elwha and Lyre River chum (Figure 1). Run timing and GSI data (Wunderlich et al. 1994) suggest the run has an early native component with peak spawning in late November, and a late introduced component with peak spawning in late December. However, one year's data cannot support firm conclusions on stock identity and timing. The small number of fish observed, coupled with the possibility of streamflow variation influencing the actual or observed timing pattern, makes several more years of survey highly desirable.

The Lower Elwha Tribe usually conducts an in-river gillnet fishery in October targeting on hatchery coho (*Oncorhynchus kisutch*). A few chum typically enter this fishery in late October, and in 1994 a total of 7 chum were incidentally taken in the tribal coho fishery (P. Crain, LET, pers. comm.). There has been no directed tribal fishery on Elwha chum for the last several years, but a sport catch of about 10 chum salmon likely occurred in the 1994-1995 season (P. Crain, LET, pers. comm.). Assuming the combined incidental tribal and sport catch in 1994-1995 was of very low maginitude, the terms "run size", "population", and "escapement" can be used interchangeably in this context.

Concurrent Genetic Analysis

The Lower Elwha Tribe took samples of chum carcass tissues over the entire 1994-1995 spawning run and submitted them to the WDFW for analysis by protein electrophoresis. These new data, when combined with the 1993-1994 data, are expected to be sufficient to examine the hypothesis that a distinct native stock still exists. A report from WDFW is expected later this year.

Objectives

The objectives of the FWS portion of the 1994-1995 Elwha chum salmon operations were to:

(1) Estimate the 1994-1995 spawning escapement using a tag-and-recovery method that is independent of fish counts based on visibility in the water, and

compare it to estimates based on fish counts and water visibility.

(2) Refine the description of river entry timing, spawning timing, in-river distribution, and age composition.

(3) Assist the Lower Elwha Tribe in completing their set of tissue samples for genetic stock identification.

(4) Identify potential habitat improvements and comment on known habitat problems.

METHODS

Spawning ground survey began on 25 October 1994, when chum salmon were expected to enter the river, based on previous years' tribal gillnet catches. However, fish tagging for population estimate was delayed until 9 November 1994 due to federal hiring restrictions. Spawner survey and tagging continued until 9 January 1995, when new carcasses ceased appearing on spawning grounds. Tagging was conducted in the mainstem Elwha River. Tag recovery consisted of spawning ground survey over most of the lower Elwha River, including its side channels, from RKM 0.64 (RM 0.4) to the One-Way Bridge at RKM 5.0 (RM 3.1), with most frequent visits to the former WDF chum survey index area (Figure 3).

Escapement Estimates

We estimated the population by the Petersen method and verified this using three independent methods based on redd count, redd area, and the area-under-the-curve.

Petersen Method

The Petersen method estimates the population by capturing and marking a known number of individuals and releasing them to mix with the total population. Then the population is resampled to obtain the proportion of marked fish in the second sample. This proportion is assumed equal to the ratio of the total fish originally marked to the total population being estimated.

Marking

We collected adult chum for marking primarily by gillnetting in the river one or two days a week from 8 November through 14 December 1994, and once again on 4 January 1995 (Table 1). High water prevented safe boat access to the river from 17 December 1994 through 2 January 1995. However, the Lower Elwha Tribal Hatchery rack was operating continually over the marking period. Hatchery staff marked all chum and released then into the river at Hatchery Road (Figure 3).

Gillnetting was conducted during daylight hours on the main channel of the Elwha River from the One-Way Bridge downstream to Hatchery Road. We fished all pools and glides that were sufficiently free of debris to allow the net to move freely downstream. We used a net type commonly used in the Elwha Tribal river fisheries. It consisted of 15-cm (6-inch) monofilament nylon webbing hung on 30 m (100 ft) of cork line and weighted with an equal length of lead-core foot line. The net was deep enough to touch bottom at all fishing sites. During fishing one person usually deployed the net from a 3.6-m (12-ft) aluminum drift boat while an assistant held the onshore end of the net and walked downstream parallel to the boat.

As soon as a fish was observed in the net, we retrieved the net and removed the fish by cutting away the entangling meshes with a knife. We noted the species of each salmonid captured and immediately released all coho and steelhead. We transferred all chum to a small floating netpen. Continuing to hold the fish, we determined the sex, measured the fork length, clipped the adipose fin, and applied a tag to the left mandible. The tags were bird bands made of Monel alloy or aluminum, sized H, J, K, N, and R, and engraved with a unique number. We chose a tag size that would fit around the entire mandible without overlap, and applied it with an oversized pliers. Then we returned the fish to the river, holding the fish into the current until the fish forcefully escaped our grasp. Chum entering the hatchery were processed similarly and trucked to the foot of Hatchery Road at RKM 0.64 (RM 0.4), where they were released into the river.

Mark Sampling

We recovered marked chum by carcass surveys on the Elwha River, including its sloughs and side channels, two or three days a week from 10 November through 16 December 1994, and from 3 January to 9 January 1995 (Table 1). High water prevented the spawner survey crew from safely reaching the spawning grounds from 17 December 1994 through 2 January 1995.

Full spawner surveys began at the One-Way Bridge at RKM 5.0 (RM 3.1) and ordinarily ended at Hatchery Road at RKM 0.64 (RM 0.4). These surveys were usually done twice a week. Occasionally the scheduled full survey was cut short due to freshets, or because extra time was required for mark sampling. In addition, spot surveys for GSI samples were conducted on the former WDF index area, which consists of the left bank side channel from RKM 1.4 to 3.3 (RM 1.0 to 1.5), and its tributary at RKM 2.1 (RM 1.3). The 15 December spot survey also included mark sampling.

The mark sample consisted of all carcasses that were sufficiently intact to allow us to measure the length, determine the sex, and ascertain whether the adipose fin had been removed. After locating the jaw tag and recording its number, we removed the fish's tail to avoid duplicate sampling on subsequent surveys.

Calculations

The chum salmon spawning escapement was estimated as:

$$N_P = n_1 \times n_2/m_2$$

Where: N_P = estimated population size,
n_1 = number of adipose-clipped, tagged fish released in gillnetting or at the hatchery,
n_2 = number of carcasses examined for marks on the spawning grounds, and
m_2 = number of adipose-clipped carcasses recovered on the spawning grounds.

For the purpose of population estimation the number of tags released was counted only until one week prior to the last spawner survey in December. This allowed tagged fish one week to reach the spawning grounds and die before carcass recovery.

The standard deviation as derived from Seber (1973) is:

$$S = N_P \times SQRT[(1/m_2) + (2/m_2^2) + (6/m_2^3)]$$

Where: S = standard deviation,
N_P = estimated Petersen population size, and
m_2 = number of adipose-clipped carcasses recovered on the spawning grounds.

Redd Count Method

An alternate chum salmon spawning escapement was estimated by the redd count method. In this method, the total number of redds constructed over the season is multiplied by the mean of each redd's maximum fish count over the season.

During full or partial spawner surveys (but not on spot checks) we marked each redd when first observed. We attached a surveying flag to a nearby shrub or tree and wrote on the flag the date, time, surveyor, and distance from the redd. We counted live fish on the redd or fish obviously associated with it. This method accounts for the tendency of chum to spawn in large groups and defines a redd as any discreet area of disturbance in the stream bottom attributable to spawning. The method accounts for the tendency of redds to coalesce over the season by including biweekly surveys during which each new redd is flagged. If fish were found in a single school over a number of coalesced redds, the maximum fish density would be figured over the original count of discreet redds.

The escapement was estimated as:

$$N_{rc} = R \times L$$

where: N_{rc} = estimated population size from the redd count,
R = cumulative new redds constructed over the season, and
L = mean, averaged over all occupied redds, of the maximum number of fish on the individual redd over the visible redd life.

Redd Area Method

A second alternate escapement was estimated by the redd area method, which is the product of the total number of redds constructed over the season, the mean of the largest area reached by each redd over the season, and the mean of the highest fish density per redd area over the season.

During full or partial spawner surveys we visually estimated the length and width of each redd to the nearest meter and counted live fish on the redd or fish obviously associated with it at each visit. From this we calculated the maximum density of fish per square meter of redd.

The escapement was estimated as:

$$N_{ra} = R \times A \times F$$

where: N_{ra} = estimated population size from the redd count,
A = mean, averaged over all redds whose area was estimated, of the maximum area covered by the individual redd over its visible life, and
F = mean, averaged over all occupied redds whose area was estimated, of the maximum density of live fish over the visible life of the redd.

Area-Under-The-Curve Method

This method is commonly used to estimate chum salmon escapement in western Washington (Ames 1984) and was also used to estimate last season's Elwha chum salmon escapement. For each survey, actual live chum salmon observed and estimated live chum salmon present (based on percent seen) are plotted over the season. Area-under-the-curve is then computed (as fish days) and divided by stream life (number of days the average spawner can be counted as a live fish in the survey area) to arrive at an escapement estimate.

The area-under-the-curve estimate was developed using 50% seen based on historic estimates of percent seen by WDFW personnel. A standard 10-day stream life was also assumed (Ames (1984).

Biological Characteristics of Spawning Run

Spawning Distribution

Spawning distribution was usually delineated by noting the river site of each observation as shown in Table 2. However, on some dates the observations from sites LC 1.5, LC 1.3, LT 1.3, and LT 1.0 (abbreviations are listed in Table 2) were combined and recorded as "Index".

Redd Life

Redd life was calculated from spawner survey counts of new redds as:

$$RL = (JD_{lv} + JD_{nv})/2 - (JD_{new} + JD_{pre})/2$$

where:

- RL = redd life in days,
- JD_{lv} = Julian date of the last survey when the flagged redd was still visible,
- JD_{nv} = Julian date when the flagged redd had become invisible.
- JD_{new} = Julian date when the redd was first flagged, and
- JD_{pre} = Julian date of the previous survey when the redd was first flagged

Life History

Biological data were taken from each fish captured for tagging and each carcass examined for marks on the spawning ground. We determined the sex, measured the fork length to the nearest cm, and took a scale sample to determine the age at spawning.

Genetic Stock Identification

We dissected eye, muscle, liver, and heart samples from each mark-sampled carcass. All tissue samples were transferred to LET for analysis by WDFW, who will report separately on the genetic composition of the run and its variation over the spawning season.

RESULTS

Escapement Estimate

Petersen Method

The Petersen population estimate was 300 fish with a standard deviation of 265 (Table 3). A total of 17 tagged fish (Table 4) was used in the estimate; these fish had been tagged early enough that spawner surveyors had a reasonable chance of recovering them before the high-flow period which began on 17 December 1994. A total of 53 carcasses were mark sampled (Table 5), from which three tags were recovered (Table 6).

Redd Count Method

Based on 58 new redds flagged over the season and a density of 4.11 fish/redd averaged over a sample of 17 occupied redds (Table 7), the escapement was estimated at 238 fish (Table 3).

Redd Area Method

Based on 58 new redds, a mean redd area of 5.94 m^2 (Table 8), and a maximum density of 1.16 fish/m^2 over the 17 occupied redds whose area was estimated (Table 9), I estimated a population of 400 fish (Table 3).

Area-Under-The-Curve Method

The total spawner escapement estimate based on the area-under-the-curve methodol (Figure 4) was 203 fish.

Biological Characteristics

Timing

Live chum first occurred on the spawning grounds on 31 October 1994, were most abundant after 9 December, and were absent from the river by 3 January (Table 5; Figure 5). Dead fish first occurred on 2 November, peaked on 5 December and again in the latter half of that month. Only one dead fish was counted on 3 January. Redds first appeared on 7 November, peaked on 5 December and again on 14 December; no visible redds remained in early January.

Distribution

By far the largest part of the run spawned in the former WDF index area (Figures 2,6). The remainder was divided between the mainstem and its side channels upstream of the index, and Boston Creek.

Redd Life

Redd life averaged 14.7 days, and ranged from 2.5 to 21.5 days, based on a sample of 24 flagged redds (Table 10).

Length, Sex, and Age Distribution

The fish measured at tagging and carcass recovery combined had fork lengths ranging from 52 to 82 cm, with a mean of 69 cm (Table 11). The overwhelming majority of spawners were four years old. Length increased with age but the length range of four-year-olds overlapped the length of age-3 and age-5 fish (Figure 7). Males had a median length about 5 cm greater than females. The ratio of males to females in the combined sample was 1.42 to 1 (Table 12).

Incidental Species

A total of 17 adult coho salmon occurred in the experimental gillnet bycatch and spawner survey (Table 13) between 2 November and 7 December 1994. A total of 23 winter steelhead (*O. mykiss*) occurred in the gillnet bycatch and spawner survey between 9 November 1994 and 4 January 1995, with greater frequency after 13 December 1994.

DISCUSSION

All population estimates underestimated the total run. Marking and spawner survey were impossible for the entire latter half of December; any fish entering and spawning in this period escaped detection. As well, all population estimates discussed below do not include an estimated 17 chum salmon taken incidentally in Elwha tribal coho fisheries and in the Elwha sport catch in 1994-1995.

Escapement Estimates

Petersen Estimate

The Petersen population estimate was valid only within the actual mark sampling period of 9 November to 16 December 1994. Flooding after 16 December made tag recovery impossible. The Petersen estimate, as applied to in-river tag-and-recovery studies, requires several assumptions:

Assumption 1: The population is closed to recruitment and immigration.

Closure implies that all fish must be available for recapture. This means they must neither die before reaching the recovery location nor stray from the river to spawn elsewhere. Pre-spawning mortality was probably low because of the very short handling time. Of the 19 tagged fish whose behavior upon release was noted, 13 swam away quickly, 5 swam away slowly, and one was disoriented before eventually recovering. Of the three fish whose tags were recovered, two had left the tagging site quickly while one had left slowly; this reflected the distribution of condition among the entire tag group. Recent broodstocking projects (WWFRO 1992) confirm our ability to handle adult chum without inducing pre-spawning mortality.

The 17 tagged fish used in the population estimate were not "lost" before the second sample, for they had at least eight days (8 December to 16 December) to reach the spawning grounds before high flows interrupted the spawner survey. Travel time from tagging to recovery ranged from 8 to 22 days, based on the three tag recoveries in this study (Table 6).

Straying was probably negligible, for all fish were captured and tagged in freshwater. Fish were captured between the bluff and Sisson's Hole (Figure 2), that is, between 0.8 and 4.1 km (0.5 to 2.6 mi) from the Strait of Juan de Fuca. Since tidal influence only extends to RKM 0.64 (RM 0.4) in extreme cases, it is reasonable that these fish were adapted to saltwater and not likely to leave the river.

Assumption 2: Marked fish have the same mortality and behavior to recovery effort as unmarked fish.

Marking did not affect recoverability on spawning grounds because technicians were trained to examine all carcasses without bias toward marked ones.

Assumption 3: Marked fish do not lose their mark.

No fin clips were lost before recovery because adipose fins could not be regenerated in the short period from tagging to recovery. All three tagged fish that were recovered had kept their tags.

Assumption 4: All marked fish are reported on recapture.

All marked fish were recognized as such, because technicians were trained to look primarily for the adipose clip. Dubious cases of jaw tag scars were avoided by not counting detached body parts or badly mutilated carcasses in the mark sample.

Assumption 5: Either the marking or recapture sample is random, or else there is random mixing of marked and unmarked fish.

Marking and recapture were planned to take a random sample over time, site, sex, and length. However, high flow throughout the latter half of December (Figure 3) prevented both tagging and tag recovery over this period (Table 1). Despite this difficulty, it was possible to examine the assumptions of the population estimate as they apply to the run up to 16 December. Although mark timing and location were biased with respect to live fish timing and carcass distribution on the spawning grounds, mark sampling was unbiased regarding length, sex, site, and date. In-river Petersen estimates typically reduce the assumption of randomness into several testable hypotheses regarding bias in marking and sampling (Hiss et al. 1982a,b).

- Tag timing. Within those time periods when the river was accessible for tagging, peak timing of tagging was biased in that it lagged behind the peak occurrence of live fish in the mainstem over which tagging took place (Table 14).

- Tag sites. Tag location was biased in comparison to distribution of live counts in mainstem. Tagging was evenly spread out from RKM 1.0 to 4.2 (RM 0.6 to 2.6), whereas most mainstem observations of live fish were at Sisson's Hole (Figure 8).

- Fish length. Fork length at tagging was unbiased with respect to distribution of carcass lengths in spawner survey (Table 8).

- Sex ratio. Sex ratio at tagging was unbiased with respect to sex ratio during carcass survey (Table 15).

- Recovery timing. Timing of mark sampling was unbiased with respect to timing of dead fish observed in spawner survey (Table 16). However, decreasing daylight hours in December caused us to mark-sample a smaller proportion of the carcasses during the peak of the run.

- Recovery sites. Location of mark recovery was not biased with respect to the distribution of total carcasses counted in spawner survey (Table 17).

Significance of Small Number of Tags Recovered

We recovered only three marks, whereas the minimum recommended tag recovery is seven (Eames et al. 1983). This suggests that the variance around the population estimate is probably larger than that calculated in this report.

Redd Count Method

Counting individual redds is feasible for estimating Elwha chum because most redds initially appeared at a size suggesting the work of one female. Counting adults per occupied redd could also be done without excessive doubt as to which fish belonged with a given redd.

The redd count method is expected to underestimate escapement in relatively turbid waters including the mainstem and right bank side channels. If the Petersen method indeed overcomes the effect of turbidity on redd counts, at least up to 16 December, then the redd count method would underestimate total escapement by 300 - 245 = 62 fish (Table 3). This suggests that roughly 62/300, or about 21% of the run spawned in waters where redds could not be seen. This bias is not large compared to the wide margins of error in the Petersen method itself.

Redd Area Method

Estimating escapement using fish per redd area is probably less accurate than estimation based directly on fish per redd. This is because of the subjective differences in redd size estimated by different survey technicians. For example, in a redd between one and two meters in width, a difference of one meter would double or halve the estimated area.

The redd area population estimate exceeds the Petersen estimate by 100 fish. This suggests, in contrast to the redd count method, that virtually no fish spawned where redds were not visible.

Area-Under-The-Curve Method

The area-under-the-curve estimate was lower than the Peterson estimate described above, assuming 50% of the spawners were observed by surveyors. If the percent observed was lower, spawner estimates would be higher and vice versa. For example, if it is assumed that the surveyors observed 100% of the spawners, the estimate would be 125 fish.

Run Status Compared to Previous Years

The total run as estimated by any method was larger than the 1993-1994 run of 153 fish described in Wunderlich et al. (1994).

The peak live and dead count was 76 fish on 12 December 1994. This was near the middle of the range for peak fish counts since 1989 given by Wunderlich et al. (1994). This recent range was the same order of magnitude as the range between 1952 and 1972 (Wunderlich et al. 1994). The concentration of spawners in a few sites resulted in many other apparently suitable spawning sites going unused. This may indicate the escapement was less than the habitat capacity in 1994-1995 and in most years for which fish counts are available.

Effect of Capture on Survival of Incidental Species

We expect very low potential pre-spawning mortality of adult coho salmon and steelhead due to capture in gillnets, since these species were not handled as long as chum, but released from the net immediately after capture.

Timing, Distribution, and Life History

Spawn Timing

Clearly the high flow event of late December made it difficult to tell when the peak of the late run segment occurred (Figure 5), but the slight decline in fish counts before 16 December may indicate that the peak had already occurred during the second week of December. Evidence for an early run segment in 1994 is best given by dead counts, which may show two peaks approximately 15 days apart. Redd count data also show two peaks but they are less distinctly separated. Neither count is totally reliable because of data gaps caused by high flows. The late segment apparently dominated in 1994-1995, whereas the early segment appeared more abundant than the late run in 1993-1994. Both years' timing data in combination indicate a relatively inactive period between early and late spawning during the second week of December.

Distribution

High turbidity in the mainstem and right bank side channels may have caused underestimation of the proportion of spawning there compared to the index and Boston Creek, where the bottom could be clearly seen on nearly every survey. However, the high escapement estimate given by the redd area method relative to the Peterson method suggests that turbidity differences may not cause a serious bias.

Distribution Compared to 1993-1994

The 1994-1995 run heavily concentrated in the index area. In contrast, the 1993-1994 run used the right bank side channels, especially Site RC 0.9, and the mainstem (Figure 6). In 1994 instream flow did not appear to block access to the index area as it did early in the 1993-1994 run as described by Wunderlich et al (1994). The artificial rock barrier and beaver dam had disappeared. However, occasional low flows and beaver activity in 1994 may have partially limited fish access to the main index channel (Site LC 1.3) upstream of the tributary (Site LT 1.3).

The upstream extent of spawning was RKM 4.5 (Site RC 2.8) in 1994-1995, and RKM 4.2 (Site MC 2.6) in 1993-1994. A chum spawning channel has been proposed for construction on the right bank between the WDFW rearing facility outfall and Sisson's Hole. The spawning channel may not attract a large part of the run since its proposed inlet would be near the upstream limit of spawning.

Preference for Low Turbidity

Elwha chum may prefer spawning in side channels with lower turbidity than the mainstem. In 1994-1994, such channels were only on the left bank; the extensive right bank side channels appeared as turbid as the mainstem.

Distribution Shift During Run

Chum seemed to reside in the mainstem for a time in 1994 before entering the side channels and sloughs to spawn (Figure 9). In contrast, in 1993-1994, fish occurring early in the mainstem appeared to remain there to spawn (Figure 10). Distribution data from 1993 support the hypothesis that new fish entered Boston Creek and the right bank side channels in mid-season, and that new arrivals entered the index area as it became available in the second half of December.

Differences in spawn timing between various river areas is not uncommon in chum salmon (Hiss et al. 1982a,b). Several factors may affect distribution shifts on the Elwha during the run. Rainfall over the season can eventually increase flow in spring-fed tributaries, primarily the one entering the index area, enabling them to support more spawning as the season progresses. High flow events can, by altering the bed form, change flow and turbidity in spawning areas, making them more or less attractive for spawning, either within the season or from one year to another. Construction and washout of beaver dams can also influence fish access to spawning grounds. These factors make it impossible to attribute different spawning habitat preferences to early and late run segments.

River stage strongly influenced surveyors' ability to reach the spawning grounds and count live fish and redds. This resulted in failure to identify spawning sites used by the latter half of the 1994-1995 run.

CONCLUSIONS

(1) The Petersen estimate gave an escapement of 300 adults, with a standard deviation of 265.

(2) The number of new redds constructed over the season multiplied by the average number of observed fish per active redd gave an escapement estimate of 238 fish.

(3) The sum of the maximum area of each redd over the season multiplied by the average number of observed fish per unit area of active redds gave an escapement estimate of 400 fish.

(4) The area-under-the-curve method gave an estimate of 203 fish, assuming 50% of spawners were observed.

(5) All methods gave an escapement higher than the 1993-1994 escapement, which was 153, as estimated by the area-under-the-curve method.

(6) An estimated 17 Elwha chum salmon were also taken in incidental tribal and sport catches in 1994-1995, and an estimated 26 Elwha chum salmon were also likely taken in incidental tribal and sport catches in 1993-1994. These additional catches were not included in Elwha run size estimates noted above for the 1994-1995 return (described in this report) or for the 1993-1994 return (described in Wunderlich et al. (1994)).

(7) A very small portion of the run, possibly representing the early native stock, returned to the river from late October to early December. A much larger portion, possibly representing introduced Walcott Slough stock from Hood Canal, returned between mid-December and early January during a generally high flow period.

(8) The early segment was much smaller relative to the total run in 1994 than in 1993.

(9) River stage and beaver activity partially controlled fish access to the left bank side channel upstream of RKM 2.1 (RM 1.3). However, these factors did not block access to the entire index area as occurred early in the 1993-1994 run.

(10) The left-bank side channel from RKM 1.6 to 3.2 (RM 1.0 - 2.0) remained the most heavily-used spawning ground in the 1994-1995 run, as in 1993-1994.

(11) Very few chum appeared to migrate upstream of Sisson's Hole at RKM 4.1 (RM 2.6). This implies that a large part of the run may not migrate to the entrance of the spawning channel proposed for construction below the existing WDFW rearing facility, unless lack of spawning gravel in this reach is indeed the reason for low chum salmon use of this reach.

(12) The City of Port Angeles water diversion structure at RKM 5.4 (RM 3.4) has little, if any effect on distribution of chum spawning, given the limited range of the current population.

RECOMMENDATIONS

(1) Use redd flagging and counts of live adults per redd to estimate the population in 1995-1996. Maximize data on fish per redd by ensuring that every redd is given a unique flag number.

(2) Extend routine spawner survey to right bank side channels at RKM 2.9 (RM 1.8), RKM 1.0 (RM 0.6), and Bosco Creek, which enters the right bank at RKM 0.3 (RM 0.2). We concur with the recommendation of WDFW (Kevin Bauersfeld, pers. comm.) that the potential of Bosco Creek for improvements in chum passage and spawning habitat be investigated.

(3) Assure constant chum access during low flow periods to all sloughs and tributaries that have spawning gravel. Small woody debris and cobbles should be moved manually as needed, particularly in the left bank side channels.

(4) Stabilize woody debris at the head of the former WDF index channel (RKM 3.2; RM 2.0) to maintain the quantity and clarity of water in the index channel.

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TABLES

Table 1. Joint FWS-Lower Elwha Tribe field schedule for estimating Elwha chum salmon escapement and collecting samples for genetic stock identification, 1994-1995.

Day	Date	Activity[A]	Done?	Agency	Comments
T	941025	SPOT	YES	LET	GSI sampling only
W	941026	SGS	YES	FWS	
M	941031	SGS	PART	FWS	Stopped due to high flow
W	941102	SGS	YES	LET	
F	941104	SGS	YES	FWS	
M	941107	SGS	YES	FWS	
Tu	941108	TAG	YES	FWS,LET	
		SPOT	YES	LET	GSI sampling only
W	941109	TAG	YES	FWS,LET	
Th	941110	SGS	YES	FWS,LET	
M	941114	SGS	YES	FWS	
Tu	941115	TAG	YES	FWS,LET	
W	941116	SPOT	NO	N/A	
Th	941117	TAG	YES	LET	
F	941118	SGS	YES	FWS,LET	
M	941121	SGS	YES	FWS	
Tu	941122	TAG	YES	LET	No catch
W	941123	SGS	YES	FWS,LET	
M	941128	SGS	YES	FWS	
Tu	941129	TAG	YES	LET	
W	941130	SPOT	NO	N/A	
Th	941201	SPOT	NO	N/A	
		RACK	YES	LET	Tagged one fish
F	941202	SPOT	YES	FWS,LET	GSI sampling only
		RACK	YES	LET	Tagged one fish
Su	941204	RACK	YES	LET	Tagged one fish
M	941205	SGS	PART	FWS	
Tu	941206	TAG	NO	LET	No data on file
W	941207	SGS	YES	LET	
Th	941208	TAG	YES	FWS,LET	
F	941209	SGS	YES	FWS,LET	

Table 1, continued.

Day	Date	Activity[A]	Done?	Agency	Comments
M	941212	SGS	YES	FWS	
Tu	941213	TAG	YES	LET	
W	941214	SGS	YES	LET	
		TAG	YES	LET	
Th	941215	SPOT	YES	LET	Included mark sampling
F	941216	SGS	PART	FWS,LET	Stopped at sundown
M	941219	SGS	NO	N/A	Canceled due to high flow
Tu	941220	TAG	NO	N/A	Canceled due to high flow
W	941221	SGS	NO	N/A	Canceled due to high flow
Th	941222	TAG	NO	N/A	Canceled due to high flow
		RACK	YES	LET	Tagged one fish
F	941223	SGS	NO	N/A	Canceled due to high flow
M	941226	SGS	NO	N/A	Canceled due to high flow
Tu	941227	TAG	NO	N/A	Canceled due to high flow
W	941228	SGS	NO	N/A	Canceled due to high flow
Th	941229	TAG	NO	N/A	Canceled due to high flow
F	941230	SGS	NO	N/A	Canceled due to high flow
Tu	950103	SGS	YES	FWS,LET	
W	950104	TAG	YES	LET	No fish captured
Th	950105	SGS	YES	FWS,LET	No fish sighted
F	950106	SPOT	YES	LET	No fish sighted
M	950109	SPOT	YES	FWS,LET	No fish sighted

[A] SGS = Spawning ground survey
TAG = Gillnetting and jaw-tagging
RACK = Hatchery rack return; all chum entering rack were tagged
SPOT = Spot check in index area for GSI samples and, on 15 December, for mark recovery.

Table 2. Elwha River sites for chum salmon jaw-tagging and spawning ground survey, 1994-1995.

River site[A]	Description	River site[A]	Description
MC 3.2	One-way Bridge to WDFW spawning channel	--	--
MC 2.8	Mainstem opposite WDFW spawning channel	RC 2.8	Right bank side channel above WDFW spawning channel outfall
MC 2.7	Mainstem above Sisson's Hole	--	--
MC 2.6	Sisson's Hole to first left bank side channel	RC 2.5	Right bank side channel below Sisson's Hole
LC 2.3	First left bank side channel below Sisson's Hole	MC 2.3	Mainstem opposite first left bank side channel
LC 2.4	Second left bank side channel below Sisson's Hole	--	--
MC 2.0	Single channel above Spruce Hole	--	--
MC 1.8	Mainstem, Spruce Hole to right bank slough	RC 1.8	Right bank slough below Spruce Hole
LC 1.5	Index area, logjam downstream to slough	MC 1.5	Mainstem, slough to Elwha Tribal hatchery outtake
LC 1.3	Index area, slough downstream to left bank tributary	MC 1.3	Mainstem, outtake to right bank side channel
LT 1.3	Left bank tributary	--	--
LC 1.0	Index area, left bank tributary to mainstem	MC 1.0	Mainstem, right bank side channel to top of Boston Creek
MC 0.9	Mainstem, Boston Creek to right bank side channel	RC 0.9	Right bank side channel
LC 0.8	Boston "Creek"	RC 0.8	Right bank mid-island slough
MC 0.8	Mainstem, right bank side channel to Boston Creek	--	--
MC 0.6	Single channel at Bluff	RC 0.6	Right bank slough
MC 0.5	Mainstem, slough to tribal hatchery outfall	RO 0.5	Elwha Tribal Hatchery outfall
MC 0.4	Mainstem, hatchery outfall to Hatchery Road		

[A] MC = Main channel; LC = Left bank side channel; RC = Right bank side channel; LT = Left bank tributary; RT = Right bank tributary; RO = Right bank outfall

Table 3. Population estimates of Elwha River chum salmon, 1994-1995.

Method	Parameter	Variable	Value
Petersen	Tagged fish released	n_1	17
	Carcasses examined for tags	n_2	53
	Tags recovered from carcasses	m_2	3
	Population estimate	N_P	300
	Standard deviation	S	265
Redd count	Total new redds over season	R	58
	Live fish per occupied redd (n = 17 redds)	L	4.11
	Population estimate	N_{rc}	238
Redd Area	Total new redds over season	R	58
	Mean area of redd (m^2) (n = 58 redds)	A	5.94
	Live fish/m^2 on occupied redds (n = 17 redds)	D	1.16
	Population estimate	N_{ra}	400

Table 4. Chum salmon gillnetted for tagging or entering hatchery rack, number tagged, and live chum counts on spawning surveys since start of 1994 adult jaw-tagging study.

Date	Julian date	Netted	Rack returns	Tagged	Counted live in mainstem
941108	312	0	0	0	A
941109	313	3	0	1	A
941114	318	B	0	0	1
941115	319	5	0	5	3
941117	321	1	0	1	A
941118	322	B	0	0	5
941121	325	B	0	0	0
941122	326	0	0	0	A
941123	327	B	0	0	6
941128	332	B	0	0	1
941129	333	5	0	5	A
941201	335	B	1	1	A
941202	336	B	1	1	A
941204	338	B	1	1	A
941205	339	B	0	0	0
941207	341	B	0	0	1
941208	342	2	0	2	A
Subtotal (for pop. est.)				17	
941209	343	B	0	0	0
941212	346	B	0	0	0
941213	347	1	0	1	A
941214	348	B	1	1	A
941216	350	B	0	0	0
941222	356	0	1	1	A
950104	369	0	0	0	A
950105	370	B	0	0	0
950109	374	B	0	0	0
TOTAL				20[C]	

A No spawner survey conducted on this date

B No gillnetting with tagging conducted in this date

C Not included in Petersen population estimate since the time until mark sampling was discontinued reduced the likelihood of tag recovery.

Table 5. Elwha chum spawn timing and number of fish examined for jaw tags during 1994-1995 spawning ground survey.

Date	Julian date	Fish counts			Redds	Mark sampled
		Live	Dead	Total		
941026	299	0	0	0	0	0
941031	304	1	0	1	0	0
941102	306	7	2	9	0	2
941104	308	5	0	5	0	0
941107	311	7	0	7	5	0
941110	314	5	0	5	0	0
941114	318	4	3	7	0	1
941118	322	9	0	9	1	0
941121	325	1	2	3	8	2
941123	327	10	0	10	7	0
941128	332	8	1	9	14	1
941205	339	19	17	36	21	8
941207	341	24	8	32	7	4
941209	343	47	4	51	21	3
941212	346	62	14	76	32	7
941214	348	59	10	69	39	8
941215	349	[A]	5	[A]	3	5
941216	350	52	19	71	29	12
950103	368	0	1	1	0	1
950105	370	0	0	0	0	0
959109	374	0	0	0	0	0
Total						53

[A] Spot check; total fish and redds not counted.

Table 6. Time and distance covered by adult chum salmon jaw tagged in mainstem Elwha River and recovered as tagged carcasses on spawning grounds in 1994.

Tag code	Tag date	Recovery date	Days elapsed	Tag site	Rec. site
K5332	15 Nov	7 Dec	22	MC 2.6	MC 2.6
K5335	29 Nov	7 Dec	8	MC 1.5	"Index"[A]
N2811	15 Nov	7 Dec	22	MC 2.6	"Index"[A]

[A] Site LC 1.0, LC 1.3, LT 1.3, or LC 1.5 in Table 2.

Table 7. Fish per redd: mean, averaged over all occupied redds, of the maximum number of fish on the individual redd over the visible redd life.

Date flagged	Site	Time	Redd no.	Peak fish date	Live count
941107	LC 1.3	1225	1	941107	1
941107	LC 1.3	1228	2	941107	1
941128	LC 1.3	1125	0	941128	2
941128	LC 1.0	1100	0	941128	4
941205	RC 1.8	1040	0	941205	2
941205	LC 0.8	1502	0	941205	2
941205	LT 1.3	1604	0	941212	9
941205	LT 1.3	1604	0	941212	10
941212	LC 1.3	1230	0	941212	2
941212	LC 1.3	1205	0	941212	2
941214	LC 0.8	1345	0	941214	3
941214	LC 0.8	1323	0	941214	6
941214	"Index"	1215	0	941214	9
941214	"Index"	1215	0	941214	9
941209	LC 1.3	0	4	941216	5
941212	LC 1.3	1320	2	941216	1
941216	LC 0.8	1511	0	941216	2
Total redds					17
Total fish					70
Mean fish/redd					4.11

Table 8. Redd area: mean, averaged over all redds whose area was estimated, of the maximum area covered by the individual redd over its visible life.

Date flagged	Site	Time	Redd no.	Maximum area date	Redd area Length(m)	Width(m)	Area(m^2)
941107	LC 1.3	1245	4	941107	3.0	2.0	6.0
941107	LC 1.3	1225	1	941107	2.0	1.5	3.0
941107	LC 1.3	1228	2	941107	2.5	1.5	3.8
941107	LC 1.3	1237	3	941107	2.0	1.0	2.0
941107	LC 1.3	1250	5	941107	2.5	1.0	2.5
941121	LC 1.3	1120	0	941128	3.5	2.0	7.0
941121	MC 2.6	920	1	941121	1.0	1.5	1.5
941121	LC 1.3	1100	2	941121	2.0	1.0	2.0
941128	LC 1.0	1100	0	941128	2.5	2.0	5.0
941128	LC 1.0	1100	0	941128	6.0	3.0	18.0
941128	LC 1.0	1100	0	941128	3.0	2.0	6.0
941128	LC 1.0	1100	0	941128	7.0	4.0	28.0
941128	LC 1.3	1125	0	941128	4.5	2.0	9.0
941128	LC 1.3	1135	0	941128	1.5	1.0	1.5
941205	RC 1.8	1040	0	941205	1.5	1.0	1.5
941205	RC 1.8	1040	0	941205	3.0	1.0	3.0
941205	RC 0.6	1230	0	941205	2.0	1.0	2.0
941205	LC 0.8	1455	0	941205	2.0	1.5	3.0
941205	LC 0.8	1502	0	941205	2.5	1.5	3.8
941205	LC 0.8	1510	0	941205	3.5	2.0	7.0
941205	LC 0.8	1510	0	941205	4.0	2.5	10.0
941205	LC 1.3	1540	0	941212	3.0	1.5	4.5
941205	LC 1.3	1550	0	941205	3.0	1.5	4.5
941205	LC 1.3	1550	0	941212	4.0	2.0	8.0
941205	LC 1.3	1550	0	941212	3.0	1.5	4.5
941205	LT 1.3	1604	0	941212	8.0	2.0	16.0
941205	LT 1.3	1604	0	941212	10.0	3.0	30.0
941209	LC 1.3	0	3	941212	6.0	2.0	12.0
941209	LC 1.3	0	4	941216	7.0	1.0	7.0
941209	LC 1.3	1250	2	941212	3.0	2.0	6.0
941209	LC 1.3	1300	0	941212	3.0	1.0	3.0
941212	LC 1.3	1150	0	941212	3.0	1.5	4.5
941212	LC 1.3	1200	0	941212	1.5	1.0	1.5
941212	LT 1.3	1220	0	941212	2.0	1.0	2.0
941212	LC 1.3	1230	0	941212	2.0	1.0	2.0

Table 8, continued.

Date flagged	Site	Time	Redd no.	Maximum area date	Redd area		
					Length(m)	Width(m)	Area(m^2)
941212	LC 1.3	1315	0	941212	2.5	1.0	2.5
941212	LC 1.3	1320	0	941212	10.0	2.0	20.0
941212	LC 1.3	1325	0	941216	6.0	3.0	18.0
941212	LC 1.3	1328	0	941212	2.0	1.5	3.0
941212	LC 1.3	1400	0	941212	2.5	1.5	3.8
941212	RC 0.6	1430	0	941212	2.5	2.0	5.0
941212	RC 0.6	1445	0	941212	3.0	2.0	6.0
941214	"Index"	1215	0	941214	2.0	1.0	2.0
941214	"Index"	1215	0	941214	2.0	1.0	2.0
941214	LC 0.8	1318	0	941214	3.0	2.0	6.0
941214	LC 0.8	1323	0	941214	1.0	1.0	1.0
941214	LC 0.8	1330	0	941214	2.0	1.0	2.0
941214	LC 0.8	1345	0	941214	4.0	1.5	6.0
941216	LC 1.3	1338	0	941216	2.0	1.5	3.0
941216	LC 1.0	1428	0	941216	4.0	1.0	4.0
941216	LC 0.8	1444	0	941216	1.0	1.0	1.0
941216	LC 0.8	1446	0	941216	10.0	1.0	10.0
941216	LC 0.8	1449	0	941216	3.0	1.0	3.0
941216	LC 0.8	1451	0	941216	2.0	0.5	1.0
941216	LC 0.8	1454	0	941216	4.0	0.5	2.0
941216	LC 0.8	1502	0	941216	3.0	2.0	6.0
941216	LC 0.8	1511	0	941216	5.0	1.0	5.0
941216	LC 0.8	1513	0	941216	1.0	1.0	1.0
Mean area							5.94
Redds observed							58

Table 9. Fish per area of redd: mean, averaged over all occupied redds whose area was estimated, of the maximum density of live fish over the visible life of the redd.

Date flagged	Site	Time	Redd no.	Maximum live count	Maximum redd area(m^2)	Live fish/m^2
941107	LC 1.3	1225	1	1	3.0	0.3
941107	LC 1.3	1228	2	1	3.8	0.3
941128	LC 1.0	1100	0	4	18.0	0.2
941128	LC 1.3	1125	0	2	9.0	0.2
941205	RC 1.8	1040	0	2	3.0	0.7
941205	LC 0.8	1502	0	2	3.8	0.5
941205	LC 1.3	1604	0	6	4.0	1.5
941205	LT 1.3	1604	0	19	46.0	0.4[A]
941209	LC 1.3	0	4	5	7.0	0.7
941212	LC 1.3	1230	0	2	2.0	1.0
941212	LC 1.3	1320	2	1	15.0	0.1
941214	"Index"	1215	0	18	4.0	4.5[A]
941214	LC 0.8	1323	0	6	1.0	6.0
941214	LC 0.8	1345	0	3	6.0	0.5
941216	LC 0.8	1511	0	2	5.0	0.4
Mean fish per square meter						1.16
Total redds observed						17

A Two coalesced redds combined.

Table 10. Redd life estimates, lower Elwha chum salmon spawning ground survey, 1994-1995.

Date flagged	Site	Time	Redd flag no.	Julian date: Previous survey	Julian date: New	Julian date: Last visible	Julian date: Not visible	Redd life
941107	LC 1.3		4	308	311	325	332	19.0
941107	LC 1.3		5	308	311	325	332	19.0
941121	LC 1.3	1120		322	325	325	346	12.0
941121	LC 1.3	1100		322	325	343	346	21.0
941121	LC 1.3	1100	2	322	325	325	350	14.0
941121	MC 1.0			322	325	325	350	14.0
941121	MC 2.6	930		322	325	325	343	10.5
941121	MC 2.6			322	325	332	346	15.5
941121	MC 2.6	1000		322	325	325	339	8.5
941128	LC 1.0		6	327	332	332	350	11.5
941128	LC 1.3	1130	1	327	332	332	370	21.5
941128	LC 1.3	1200		327	332	332	370	21.5
941128	LC 1.3	1130	2	327	332	332	370	21.5
941128	LC 1.3	1130		327	332	332	370	21.5
941128	MC 1.0	1100	1	327	332	332	350	11.5
941128	MC 1.0	1100	2	327	332	332	350	11.5
941205	LC 1.3	1140		332	339	339	370	19.0
941205	LC 1.5	1130		332	339	339	370	19.0
941209	LC 1.3		1	341	343	343	346	2.5
941209	LC 1.5	1200		341	343	343	370	14.5
941209	LC 1.5	1604		341	343	343	370	14.5
941212	LC 1.3	1150		343	346	346	370	13.5
941212	LC 1.3	1328		343	346	346	370	13.5
941212	MC 1.0	1400	1	343	346	346	350	3.5

N = 24
Minimum = 2.5
Maximum = 21.5
Mean = 14.7
Standard deviation = 5.3

Table 11. Fork length of adult chum in Elwha River experimental gillnet catch, 1994. Length distribution is compared to that of carcasses in spawning ground survey over the 1994-1995 run using the Kolmogorov-Smirnov test (Sokal and Rohlf 1973) for goodness of fit.

	Observed distribution (tagging)		Expected distribution (spawning ground survey)			
Fork length	Occurrence	Cumulative	Occ.	Cum.	Expected[A]	d[B]
52	0	0	1	0.5	0.0	0.0
58	0	0	2	1.0	1.0	1.0
62	0	0	1	0.5	1.5	1.5
63	0	0	1	0.5	2.0	2.0
64	0	0	1	0.5	2.4	2.4
65	1	1	3	1.5	3.9	2.9
66	1	2	2	1.0	4.9	2.9
67	0	2	2	1.0	5.9	3.9max
68	5	7	2	1.0	6.8	0.2
69	1	8	4	2.0	8.8	0.8
70	3	11	3	1.5	10.2	0.8
71	2	13	3	1.5	11.7	1.3
72	1	14	0	0.0	11.7	2.3
73	0	14	2	1.0	12.7	1.3
74	2	16	0	0.0	12.7	3.3
75	1	17	4	2.0	14.6	2.4
76	0	17	2	1.0	15.6	1.4
77	0	17	3	1.5	17.1	0.1
78	3	20	1	0.5	17.6	2.4
79	0	20	1	0.5	18.0	2.0
80	0	20	2	1.0	19.0	1.0
82	0	20	1	0.5	19.5	0.5

d_{max} = 3.9
n = 20
$D = d_{max}/n$ = 0.19
$D_{0.2}$ = 0.23
$P > 0.2$ (NS)

[A] Cumulative occurrence on spawning grounds adjusted to represent a sample size of 20.

[B] Absolute value of difference between observed cumulative count in tagging operations and expected cumulative count based on spawning ground survey.

Table 12. Age and sex distribution of lower Elwha chum salmon from combined experimental gillnetting and carcass survey data.

Age	Male	Female	Total
3	1	5	6
4	31	17	48
5	2	2	4
Total	34	24	58
Ratio	1.42	1	

Table 13. Incidental species captured in experimental gillnetting for Elwha River chum salmon or observed live on chum spawner survey, 1994-1995.

Date	Julian date	Operation	Coho	Steelhead
941102	306	Spawner survey	6	0
941109	313	Gillnet	1	1
941115	319	Gillnet	3	1
941129	333	Gillnet	5	2
941207	341	Spawner survey	2	2
941213	347	Gillnet	0	9
950104	369	Gillnet	0	8
Total			17	23

Table 14. Adult chum timing in Elwha River experimental gillnet catch. Timing is compared to timing of live fish counts in mainstem spawning ground survey over the same period using the Kolmogorov-Smirnov test (Sokal and Rohlf 1973) for goodness of fit.

Date	Julian date	Observed distribution: Number tagged	Observed distribution: Cumulative frequency	Expected distribution: Number surveyed	Expected distribution: Cumulative frequency	d[A]
941109	313	1	1		0	1
941114	318		1	1	1	0
941115	319	5	6	3	4	2
941117	321	1	7		4	3
941118	322		7	5	9	2
941123	327		7	6	15	8
941128	332		7	1	16	9(max.)
941129	333	5	12		16	4
941201	335	1	13		16	3
941202	336	1	14		16	2
941204	338	1	15		16	1
941207	341		15	1	17	2
941208	342	2	17		17	0

$d_{max} = 9$

$n = 17$

$D = d_{max}/n = 0.529$

$D_{.01} = 0.380$

$P < 0.01$

[A] Absolute value of difference between observed and expected values.

Table 15. Adult chum sex ratio in Elwha River experimental gillnet catch, 1994. Sex ratio is compared to that of carcasses on spawning grounds, 1994-1995 using the chi-squared test for goodness of fit.

Sex	Observed distribution (tagging)	Expected distribution Tag recovery	Expected[A] frequency
M	12	30	12.5
F	8	18	7.5
Total	20	48	20.0
M/F ratio	1.50	1.67	

Chi squared = 0.053
df = 1
P < 0.9 (NS)

[A] Adjusted for n = 20.

Table 16. Timing of mark sampling on chum carcasses on Elwha River spawning ground survey, 1994-1995. Timing is compared to that of total carcasses counted on spawning grounds, using the Kolmogorov-Smirnov test (Sokal and Rohlf 1973) for goodness of fit.

			Observed distrib.		Expected distribution			
Date	Julian date	Type survey	Carcass exam.	Cum. freq.	Chum carc.	Cum. freq.	Expected.[A]	d[B]
941102	306	Full	2	2	2	2	1.3	0.7
941114	318	Full	1	3	3	5	3.2	0.2
941121	325	Full	2	5	2	7	4.5	0.5
941128	332	Full	1	6	1	8	5.1	0.9
941205	339	Full	8	14	17	25	16.0	2.0
941207	341	Full	4	18	8	33	21.1	3.1
941209	343	Full	4	22	4	37	23.7	1.7
941212	346	Full	7	29	14	51	32.6	3.6[C]
941214	348	Full	8	37	10	61	39.0	2.0
941215	349	Spot	5	42	5	66	42.2	0.2
941216	350	Part	12	54	19	85	54.4	0.4
950103	368	Full	1	55	1	86	55.0	0.0

$d_{max} = 3.6$

$n = 55$

$D = d_{max}/n = 0.066$

$P > 0.2$

A Adjusted for n = 55.

B Absolute value of difference between expected and observed cumulative frequencies.

C Maximum value.

Table 17. Geographic distribution of mark-sampled chum salmon carcasses on spawning grounds, 1994-1995. Distribution is compared to that of all carcasses counted on spawning grounds over the same period, using the chi-squared test for goodness of fit.

Sites	Observed distribution (mark sample)	Percent Sampled	Expected distribution Spawner survey	Expected[A] mark sample
Index (Survey sites LC 1.0 thru LC 1.5)	29	59.2%	49	30.6
Sisson's Hole (Site MC 2.6)	14	58.3%	24	15.0
All other sites	10	83.3%	12	7.5
Total	53	62.4%	85	52.1

Chi squared = 0.988
df = 2
P < 0.9 (NS)

[A] Adjusted for n = 53

FIGURES

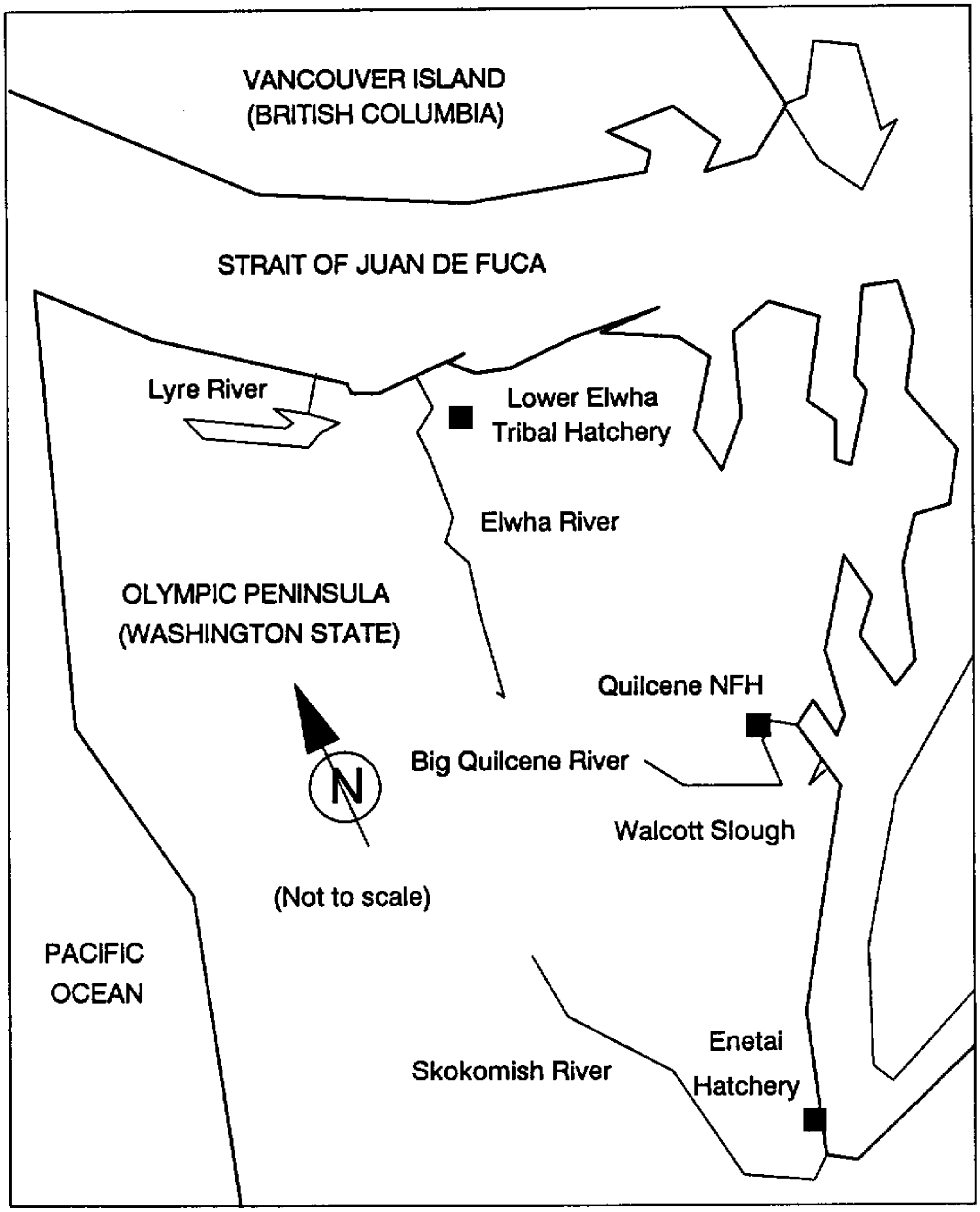

Figure 1. Olympic Peninsula of Washington State, showing Elwha River and chum salmon broodstock sources for Lower Elwha Tribal Hatchery.

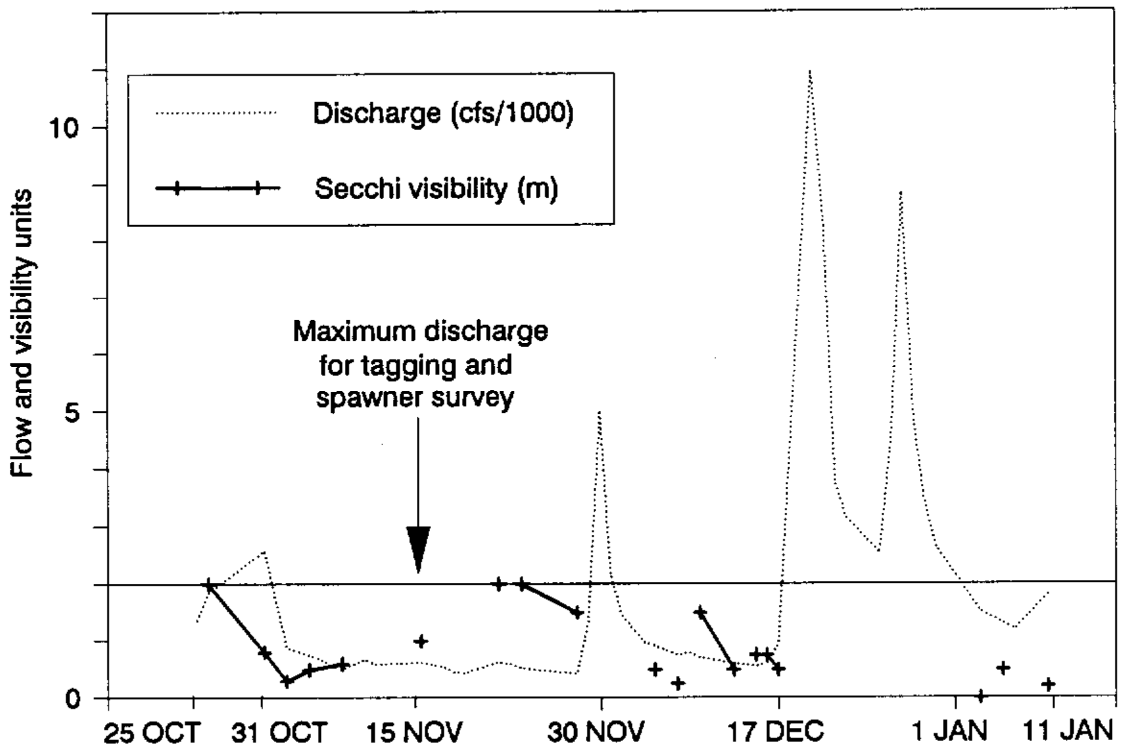

Figure 2. Mean daily discharge of Elwha River at Glines Canyon (RKM 21; RM 13), and Secchi disk visibility at One-Way Bridge (RKM 5.0; RM 3.1), during 1994-1995 chum salmon run.

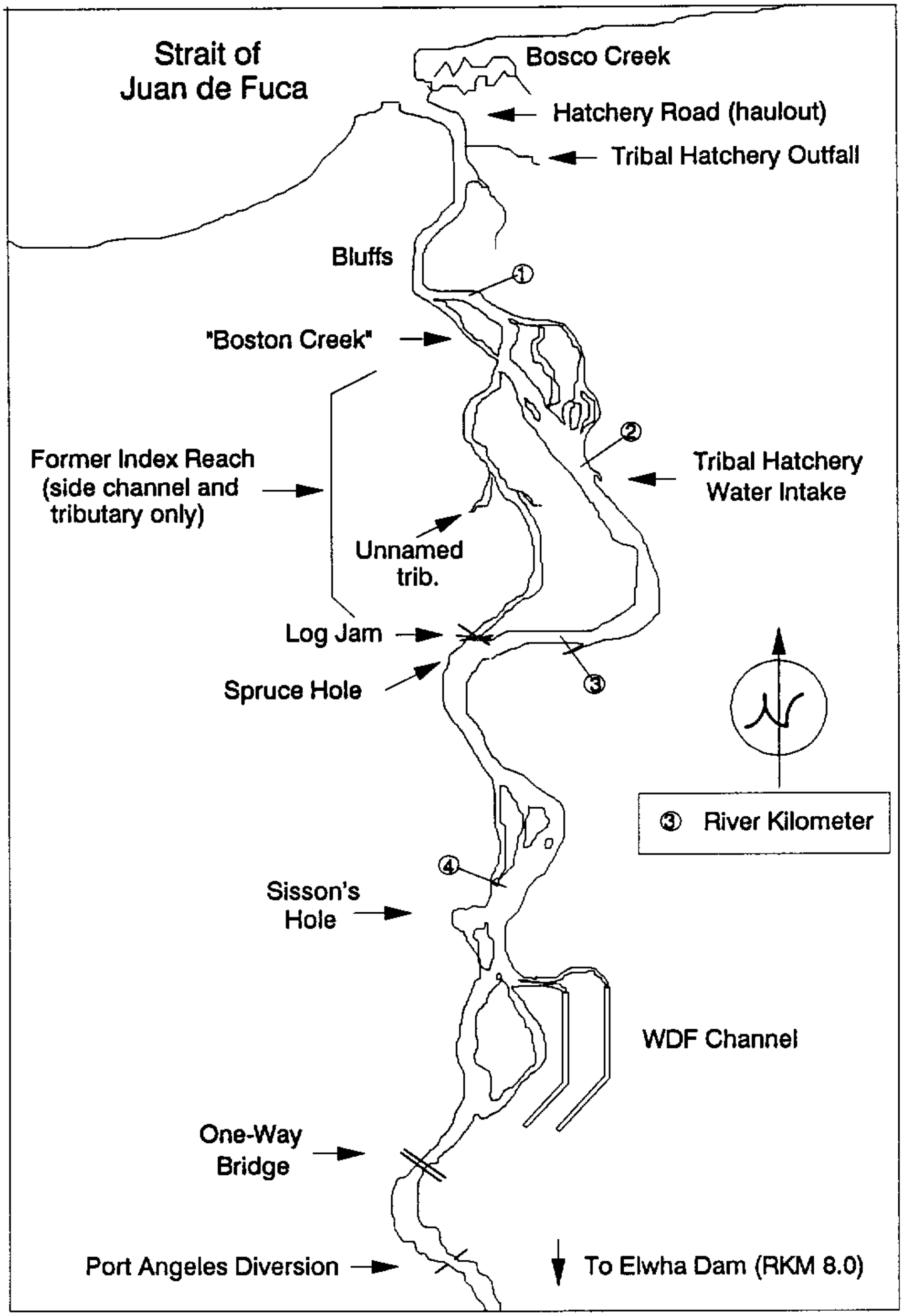

Figure 3. Lower Elwha River, showing jaw tagging and spawning ground survey sites for adult chum salmon, 1994-1995.

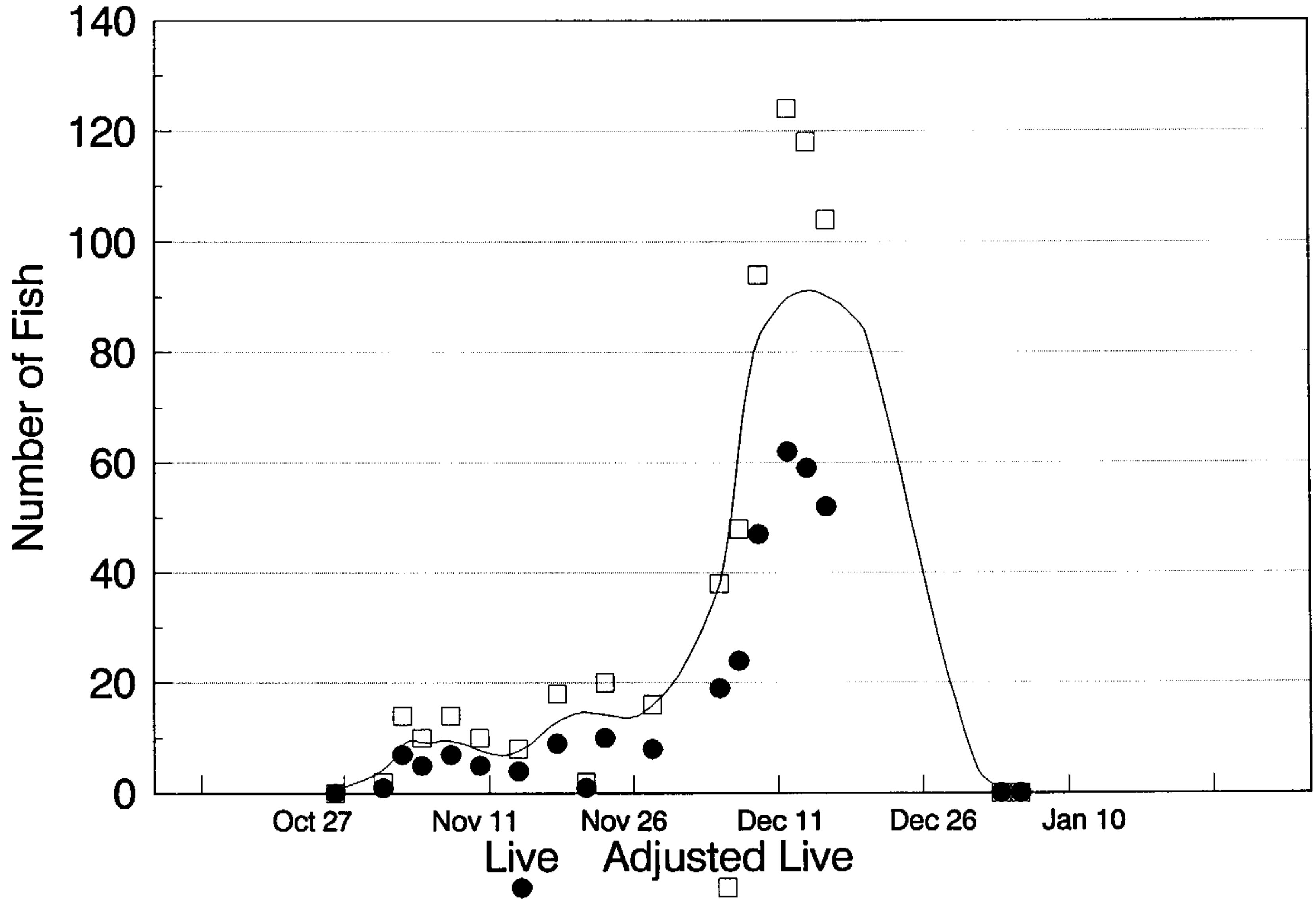

Figure 4. Plotted curve of live fish observed and estimated live fish present based on assumed percent seen each survey (Source: J. Uehara, WDFW, pers. comm.).

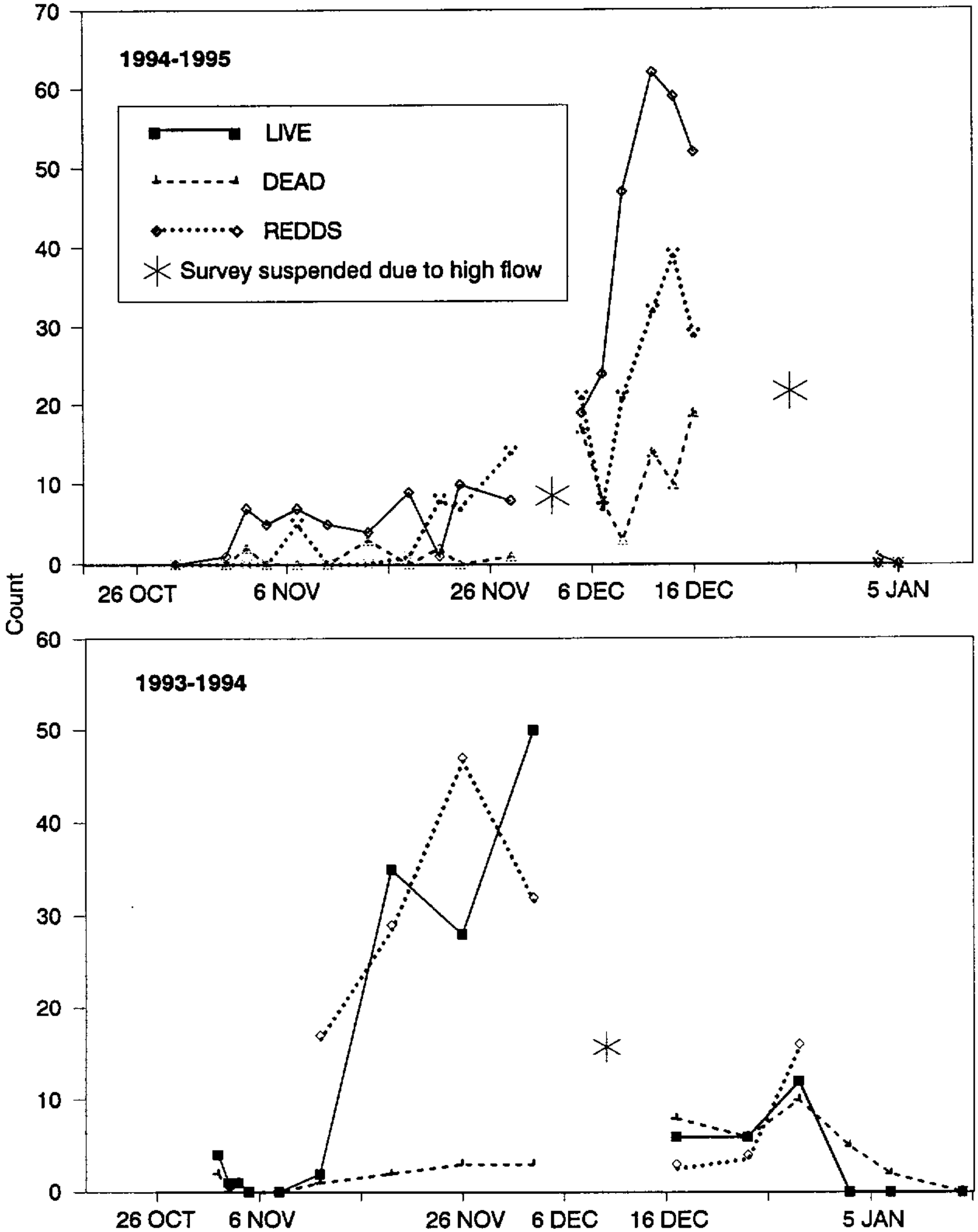

Figure 5. Timing of live chum salmon, carcasses, and redds on Elwha River in the 1994-1995 and 1993-1994 return years.

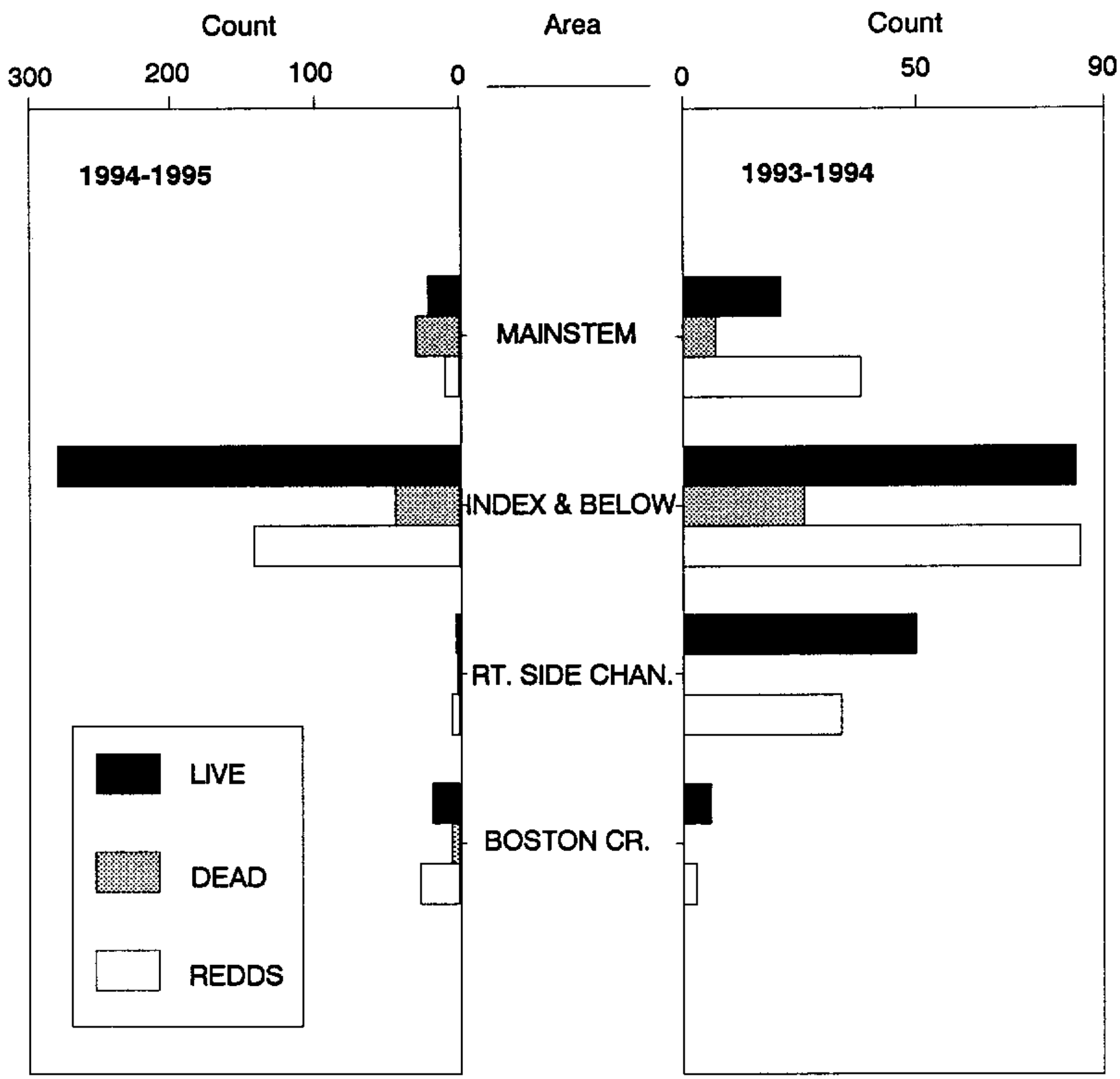

Figure 6. Chum salmon spawning distribution by area, 1994-1995 run compared to 1993-1994.

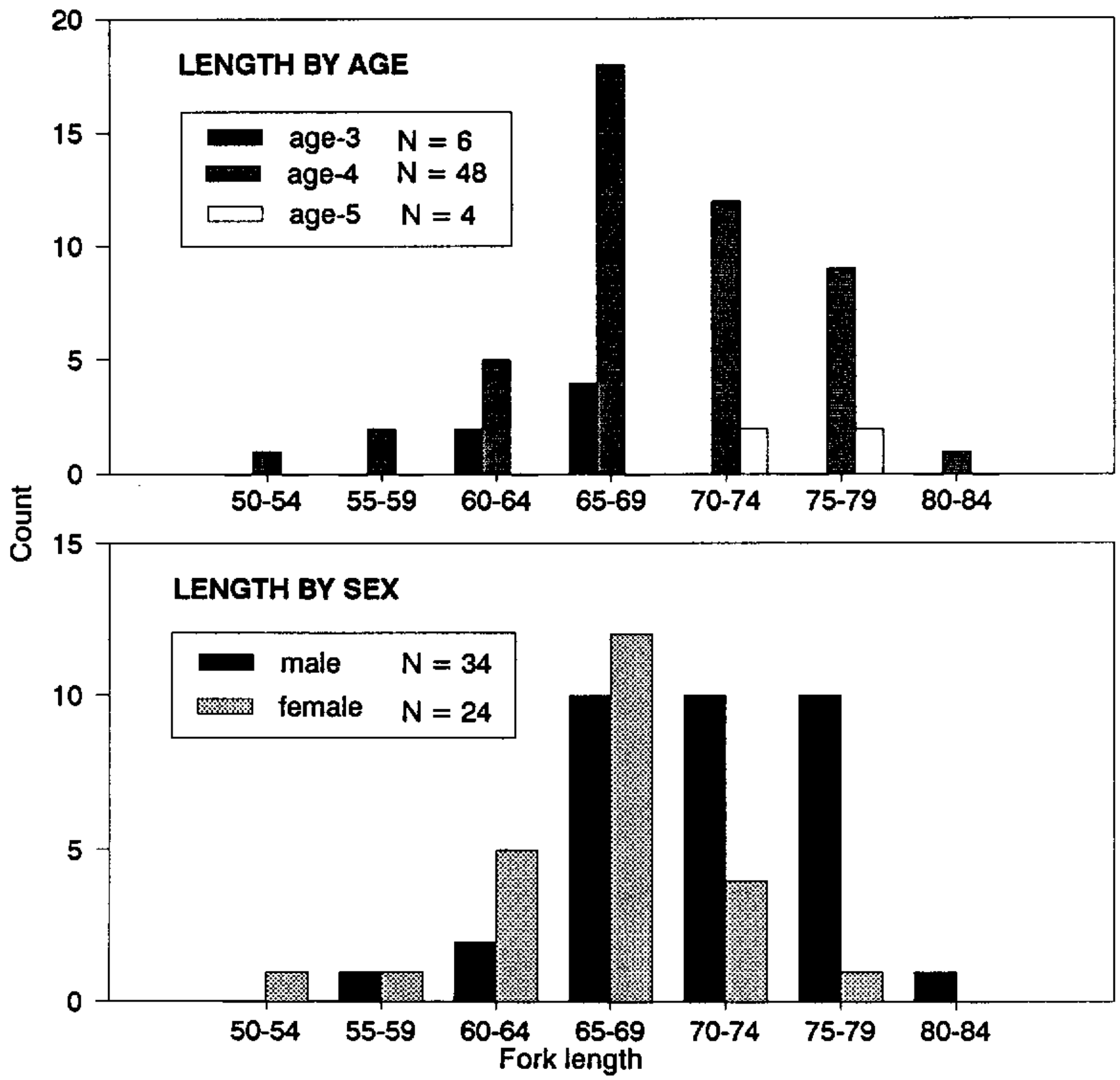

Figure 7. Fork length distribution of chum salmon collected in experimental river gillnet and carcasses examined on spawning grounds, Elwha River, 1994-1995.

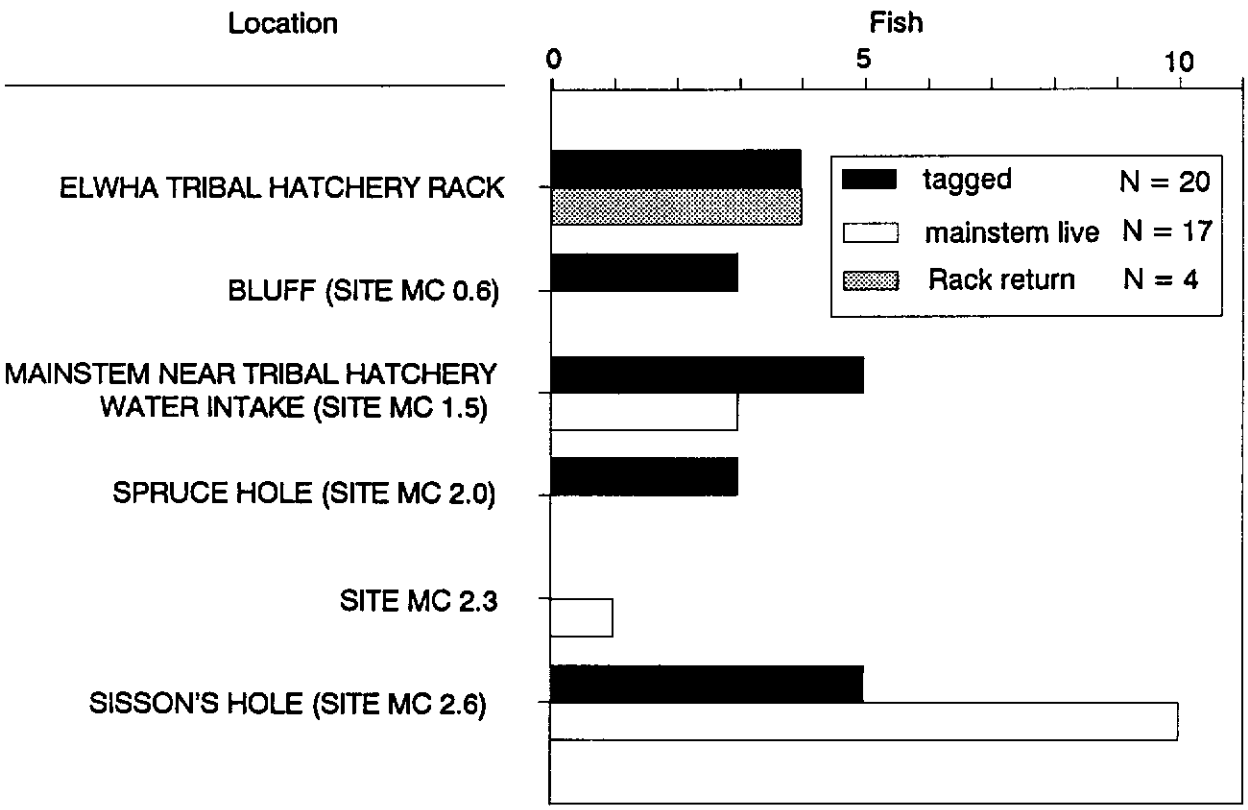

Figure 8. Distribution of chum salmon gillnetted for jaw tagging on mainstem Elwha River in 1994, compared to distribution of live chum counted in mainstem Elwha spawner survey, 1994-1995.

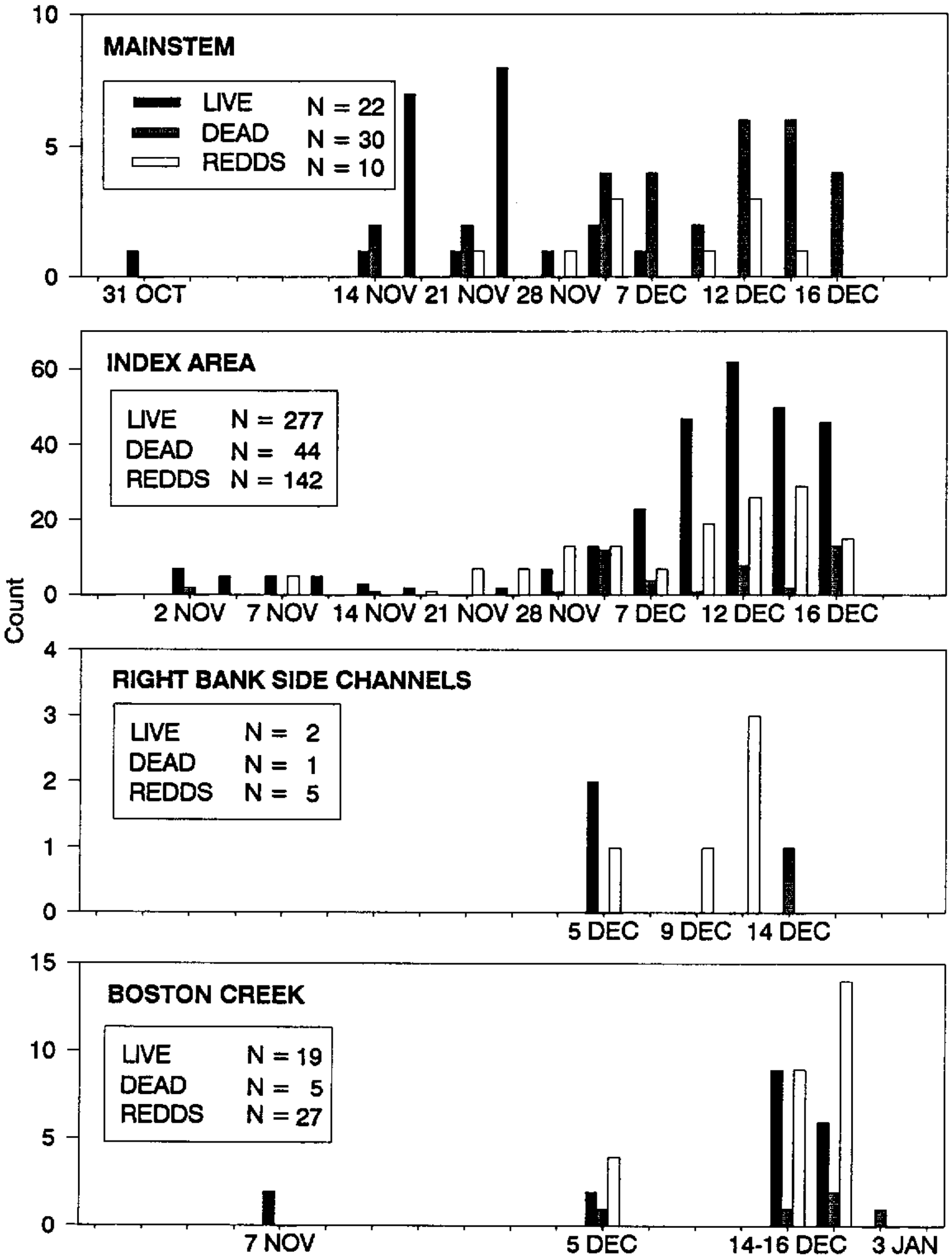

Figure 9. Shift in spawning area of Elwha chum salmon over the 1994-1995 run.

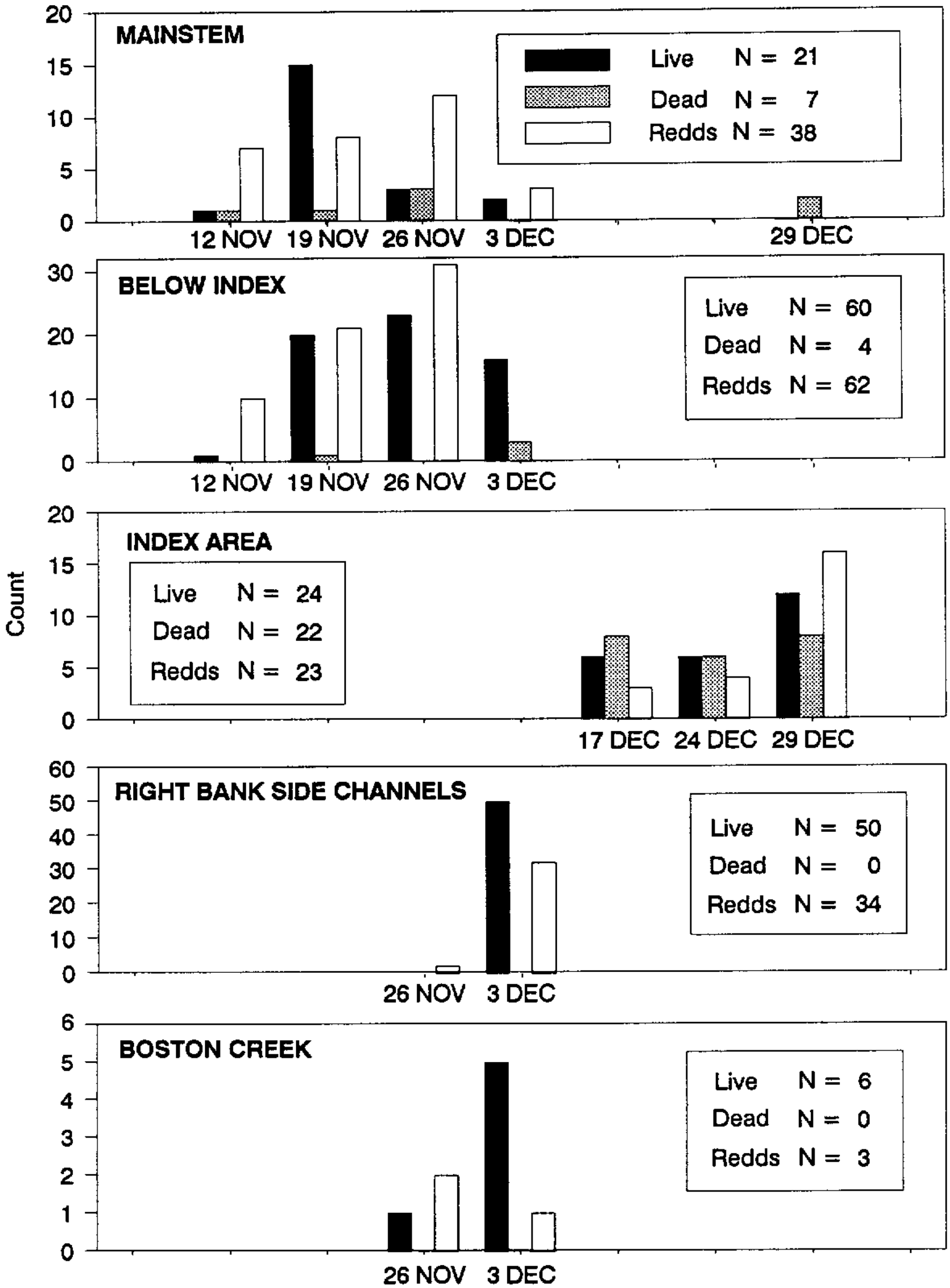

Figure 10. Shift in spawning area of Elwha chum salmon over the 1993-1994 run. Source: Wunderlich et al. (1994).